Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, August : 2023

DESIGN AND ANALYSIS OF A SUPERSONIC JET “AERION AS2 AIRCRAFT WING”

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Abstract—

A supersonic business jet called the Aerion AS2 was developed by Lockheed Martin and Aerion Corporation. Using supersonic laminar flow technology, the AS2 will fly at Mach 1.5, and the wing design will reduce the aerodynamic drag by 20%, allowing for lower fuel consumption and longer travel ranges. There will be room for up to 12 people in the cabin.

In this project here considering two NACA series airfoil shapes (NACA 2412, NACA 4412) and developed swept back wing with ribs and stringers by using cad tool (solid works) then analyzed both wing structures with static and flow boundary conditions by using CAE tool (Ansys workbench), and calculating results like deformation, stress, strength and coefficient of lift and drag values. Finally conclude that which airfoil shape can reduce the drag values and we suggest that airfoil shape is suitable for our Aerion as-2 model

CAD TOOL: solid works

CAE TOOL: Ansys workbench

(Keywords: Aerion as-2, CFRP, Al-7475, NACA 2412, NACA 4412,)

INTRODUCTION

A supersonic business jet called the Aerion AS2 was developed by Lockheed Martin and Aerion Corporation. Aerion reported at the May 2014 EBACE that it is updating its past Aerion SBJ with a bigger lodge, more reach and three yet vague motors for a $100 million or more objective cost, it expects to fly a model in late 2018/mid 2019 and confirm the plane in 2021. At the EBACE in May 2015, a unit cost of US$120 million was anticipated. In 2015 it was planned to enter administration in 2023. In May 2017, Aerion was expecting to send off it in mid-2018.

In December 2017, Aerion and Lockheed Martin declared they will investigate its joint advancement without Airbus, expecting to fly in 2023 and to be certificated in 2025.

Specifications (AS2)-

General characteristics

- Crew: 2
- Capacity: 8–12 passengers
- Length: 170 ft (52 m)
- Wingspan: 77 ft (23 m)
- Height: 22 ft (6.7 m)
- Wing area: 1,511 sq ft (140.4 m2)

Here we considered airfoils NACA 2412 & NACA 4412 and materials Al-6061 & Al-7475 and carbon fiber which are mostly used in supersonic jets and analyzed the results.

DESIGN OF WING RIB

NACA 2412 wing design

The below model shows keypoints of NACA 2412 model

The sketch above must meet three requirements: the sketcher must be closed, there must be no open end, and there must be no overlapping. We must construct our model by

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ISSN: 0970-2555
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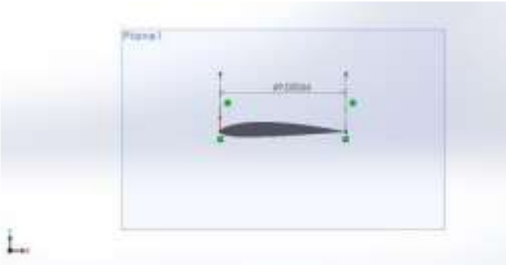
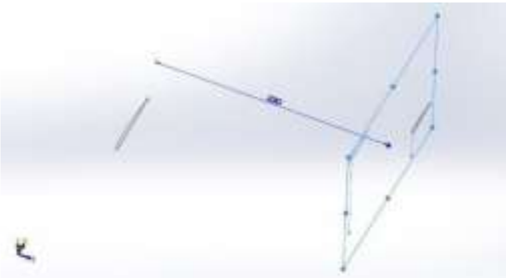
adhering to these requirements. After the sketch is finished, click OK, and the model below will appear.

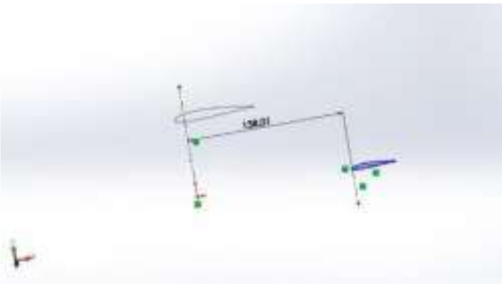
In order to adhere to the aforementioned guidelines, we use the loft option in Sketcher to create the above shape without leaving any open ends.



Here chord length is 69.03 mm, and to crate wing tip create another plane with a distance of 230mm and project sketcher on that plane with 0.5 scale factor

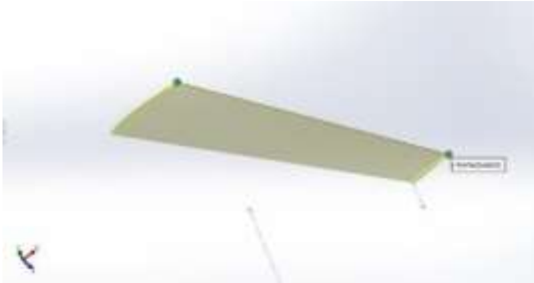


From wing root to wing tip distance is 230mm which is shown in above figure

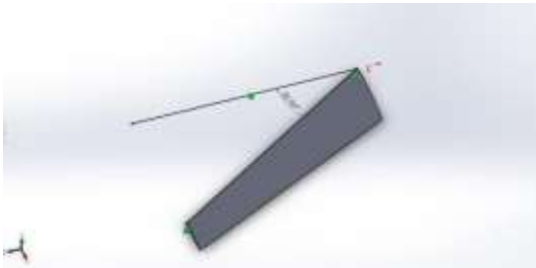


In swept back wing the dimensions and sizes are not same for both wing tip and root, in this model here we maintain 1:2 ratio to tip to root, to maintain 31degree swept angle here we maintain 138mm distance root leading edge to tip leading edge, this 138mm creates 31degree angle in 3d model.

After creating sketches on both planes select loft option - select wing root - wing tip - ok

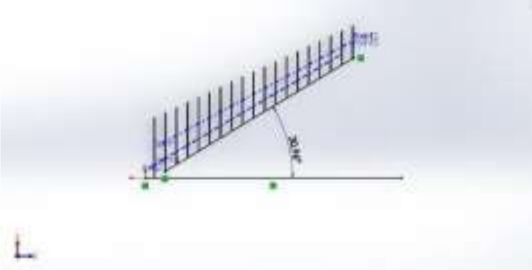


And then we get above shape and the opening end should be same side for both sketches which are shown in green colour in above image, otherwise loft option won't work.



The above image is complete wing structure of our NACA 2412 series. To create internal parts of the aircraft we cut down our wing into no of parts and we call them as ribs, to create ribs take one plane with distance of 1.15mm and project sketcher on it then cut with 11.5mm width and repeat this process to the end of the model finally we get below model

Here we have rib thickness 1.15mm and distance between each rib is 11.5mm



To insert stringers into ribs here we cutting our model with stringer dimensions,

The above image shows stringer dimensions with distance, here following 1:2 ratio in stringer dimensions also it means at wing root we have 3mm diameter and wing tip we gave 1.5mm diameter.

After crating sketcher use loft cut to cut down the model and then will get above image.

Stringer

The below image shows stringer dimensions with distance, here following 1:2 ratio in stringer dimensions also it means at wing root we have 3mm diameter and wing tip we gave 1.5mm diameter. To create wing stringer we use loft option only

Wing assembly

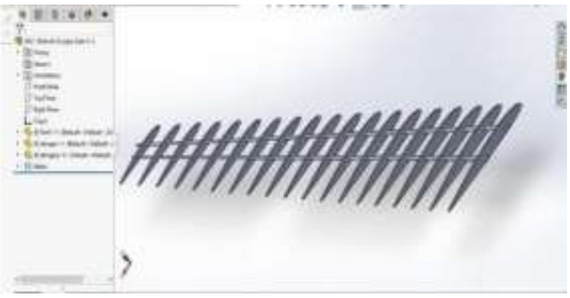
After completing individual designs of our wing structure here we import into assembly window and then constrain them with require boundary conditions

First import ribs-ok

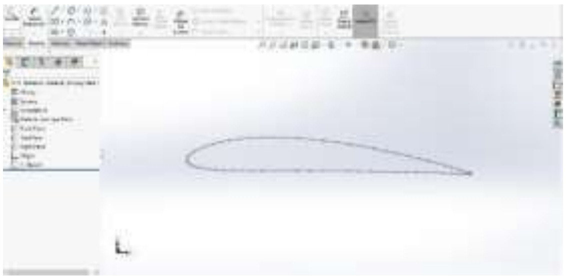
Import stringer-select coincident-select hole in rib-ok

Then select one face of stringer-select rib face-ok

Repeat same process for another stringer also



NACA 4412 wing



Final wing structure of NACA 4412

Material selection

Al-7475

Density (kg/m^3): 2810

Young's modulus (Pa): 71.7e9

Poisons ratio: 0.33

Yield strength (Mpa): 462

Al-6061

Density (kg/m^3): 2700

Young's modulus (Pa): 68.9e9

Poisons ratio: 0.33

Yield strength (Mpa): 276

CFRP

Density (kg/m^3): 1750

Young’s modulus (Pa): 70e9

Poisons ratio: 0.29

Yield strength (Mpa): 600

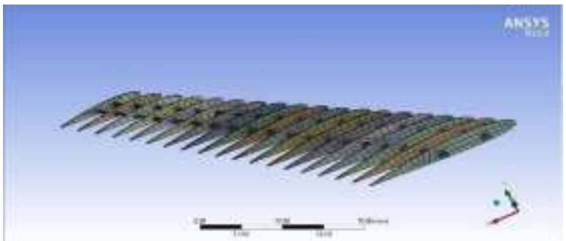
STRUCTURAL ANALYSIS

Geometry- right click- import geometry- import iges format model

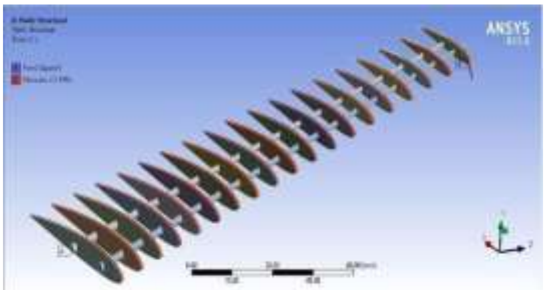
Model is imported from pro-e tool in IGES format.

After selecting the materials, now create the meshing for each object. Meshing means converting one part into a number of parts.

Meshing



Boundary condition



Static structural - supports- fixed support- select stringers

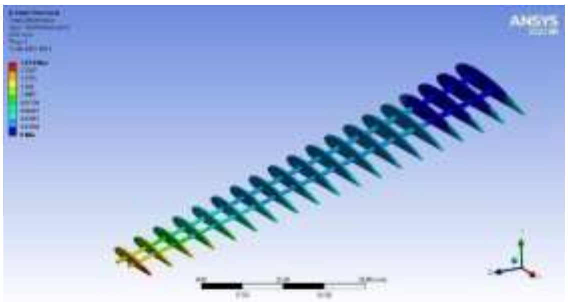
Loads – pressure- on ribs- 2.5Mpa

After completion of boundary conditions here we have check results by solving. Just click on solve option and select results like deformation, stress, Safety factor.

NACA 2412 WING RESULTS

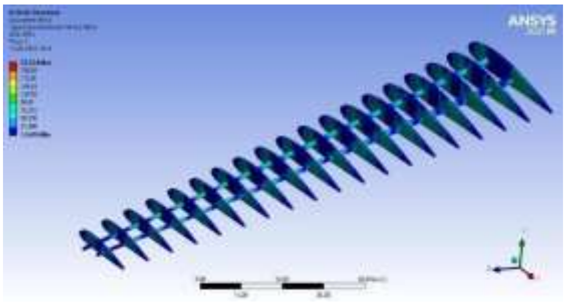
Material - CFRP

Deformation



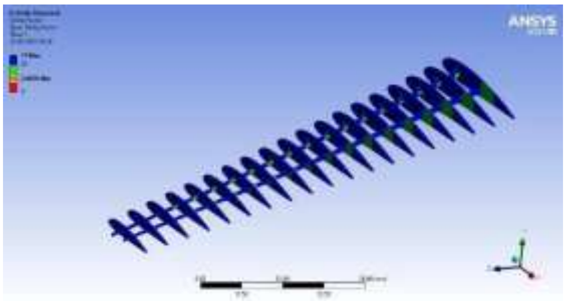
Above wing is made up of CFRP material, and here cross section used NACA 2412, and applied boundary condition on it 2.5Mpa, from the image, maximum deformation values acting at wing tip, and it has maximum deformation value of 1.974mm, and minimum deformation value is acting at wing root, and the value is 0mm.

STRESS



Above wing is made up of CFRP material, and here cross section used NACA 2412, and applied boundary condition on it 2.5Mpa, from the image, maximum stress values acting in between ribs and stringers, and it has maximum stress value of 223.24MPa, and minimum stress value 1.2419Mpa.

Safety factor

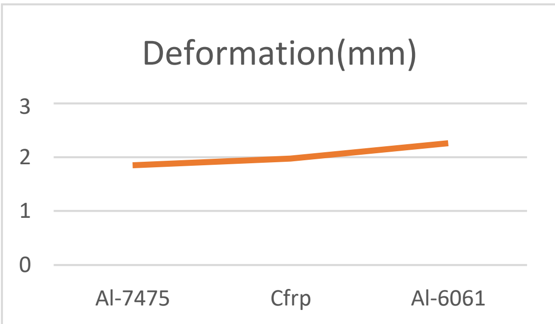


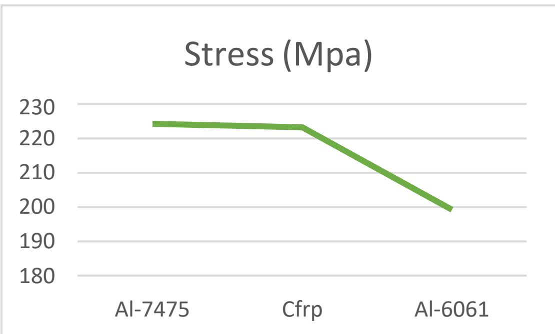
Above wing is made up of CFRP material, and here cross section used NACA 2412, and applied boundary condition on it 2.5Mpa, from the image, safety factor values are noted. Safety factor value indicates object strength. By knowing this safety factor results it is able to calculate how strong object is. From the results, contact between stringer and ribs has minimum safety factor value is 2.6876. In addition, the maximum safety factor value is 15. From minimum values, it is clear that object has required strength to bear applied boundary condition on it.

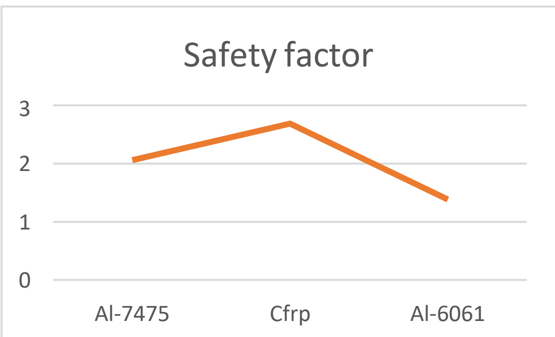
Table-

NACA 2412	Al-7475	CFRP	Al-6061
Deformation(mm)	1.8527	1.974	2.2615
Stress (Mpa)	224.24	223.24	199.24
Safety factor	2.0603	2.6876	1.3852

Graphs





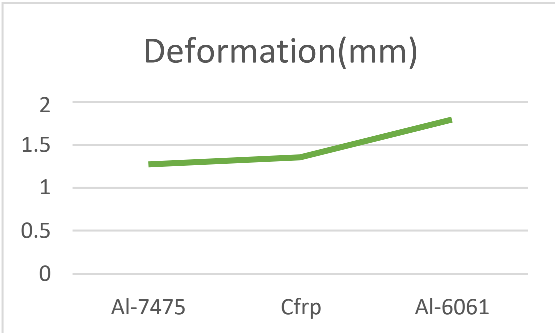


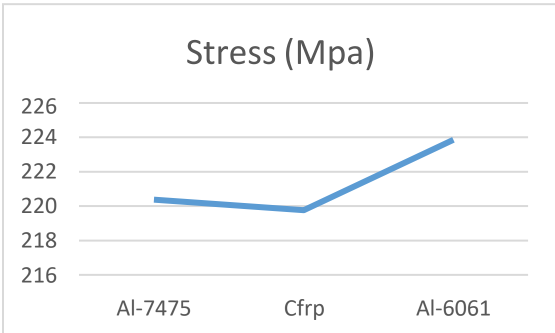
Similarly Deformation, Stress and Safety factor results are calculated for NACA4412 wing structure with Al-7475,CFRP and Al-6061 material.

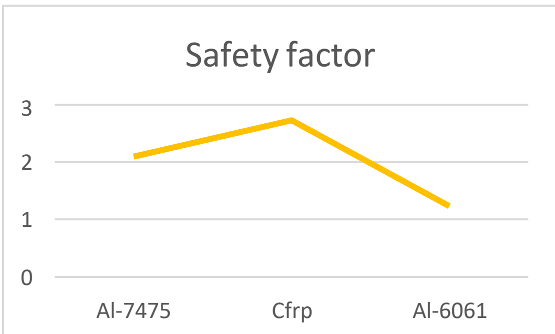
NACA 4412 RESULTS

NACA 4412	Al-7475	CFRP	Al-6061
Deformation(mm)	1.2711	1.3537	1.7941
Stress (Mpa)	220.37	219.76	223.86
Safety factor	2.0965	2.7302	1.2329

Graphs







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Modal analysis (Dynamic Analysis)

The speed at which an object vibrates unaffected by external forces is known as its natural frequency. Every level of opportunity of a body has a one of a kind regular recurrence signified by ωn (omega file n). The recurrence (omega) is equivalent to the speed of vibration separated by the frequency (lambda). Different equations for computing normal frequencies rely upon the vibrating framework. Normal frequencies can be undamped or damped relying upon whether the framework is vigorously damped. Sound waves create a moving body by diluting the square of the damping ratio by the square of the damped natural frequency, which is the sum of the set of natural frequencies.

By knowing these results, it is easy to calculate how strong developed model in vibrating conditions. Natural frequency results are calculated for both airfoil structures with different materials and results are tabulated below.

Results

Table

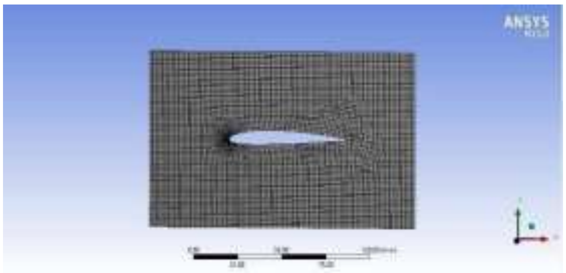
NACA 4412 wing modes	Al-7475	CFRP	Al-6061
Mode1(Hz)	34.796	42.006	34.708
Mode2(Hz)	106.79	128.54	106.16
Mode3(Hz)	185.33	222	192.82
Mode4(Hz)	232.65	279.63	232.29
Mode5(Hz)	417.47	501.34	415.95
Mode6(Hz)	448	544.69	500.93

NACA 4412 wing modes	Al-7475	CFRP	Al-6061
Mode1(Hz)	46.45	56.065	45.702
Mode2(Hz)	132.16	159.39	132.91
Mode3(Hz)	197.95	237.17	204.12
Mode4(Hz)	262.47	315.87	262.88
Mode5(Hz)	401.14	480.84	440.29
Mode6(Hz)	455.61	538.32	458.25

FLOW ANALYSIS

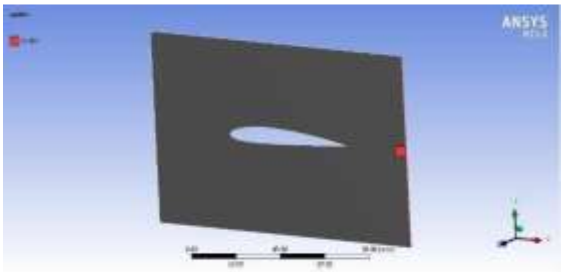
In Flow analysis Coefficient of lift and drag values are calculated for both airfoil structures by considering wind velocity as 330 m/s.

After importing model select fine mesh and the above image shows complete meshing



Now select leading edge and right click →named selection→ name as inlet→ok

After that select trailing edge-→name as outlet →ok



Then after select →density based results→ok

Boundary conditions →select inlet→inlet velocity→330m/s→ok

Result→coefficient of drag→ok

Then select calculation→no of iterations→500→ok

Results-

Wing	Coefficient of Lift	Coefficient of Drag
NACA 2412	0.03	0.11
NACA 4412	0.04	0.07

From the above results here, we can say that NACA 2412 wing series has high drag values than NACA 4412 And also NACA 4412 is having better coefficient of lift values compare to 2412 series

Finally, we conclude by above results NACA 4412 is better wing series for our aircraft.

CONCLUSION

To suggest a wing series for Aerion As-2 aircraft here we took 2 NACA series (NACA 2412, NACA 4412) and developed a swept back wing structure with ribs and stringers with swept angle 31 degrees by using cad tool (solid works), here we analysing our models with static and dynamic and air flow boundary conditions,

In static and dynamic analysis, we consider al-6061 is an existing material and Al-7475, CFRP are new materials. In static analysis we applied 2.5Mpa pressure on both models and calculated results for each material, NACA 4412 wing structure has less stress values than NACA 2412 in each case and it has good safety factor values for CFRP material.

To know the natural frequency values here we also analysing our model with dynamic loading conditions, in this process we took mode shapes to calculate the values on each model/material. from the natural frequency values, we can say CFRP with NACA 4412 wing structure has high frequency range than other model/material, by only static and dynamic results we cannot suggest one aircraft wing structure, to get more accurate here we also performing flow analysis on each structure

In flow analysis we took wind velocity as 330m/s and calculated coefficient of lift and coefficient of drag values, in flow analysis also we got less drag values for NACA 4412 wing series only.

Finally, thesis can conclude NACA 4412-wing series satisfying all static and dynamic and flow analysis results, suggest NACA4412 wing structure with CFRP material for the Aerion as-2 aircraft.

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